Final Report

Short-Term-Mobility Stay at CNR-ITAE

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Introduction

The adsorption heat exchanger (AdHEX) is the core component of an adsorption heat pump or chiller. The development of new adsorber concepts requires specific experimental activities aimed to assess the heat and mass transfer properties of the combined system "sorbent material & heat exchanger" as well as to measure dynamically its global performance under typical operating conditions.

Mainly fixed beds of adsorbent with different grain sizes have been developed and characterised at CNR-ITAE in the last years (e.g. [1],[2]). The aim of the present activities was to test an AdHEX directly coated with a layer of adsorbent material SAPO34 under typical operation conditions with a focus on the dynamic behaviour. Cooling power and the coefficient of performance (COP) are determined for different cycle times.

Experimental

Adsorption Heat Exchanger

Two state-of-art fin-tube heat exchangers are used as AdHEX (see Figure 1). The tubes are made of copper, the fins from aluminium. The sorption material is directly coated onto the surface of the fins by a partial support transformation (PST) method [3] patented by the Sortech AG, Halle, Germany. The two AdHEX only differ in the amount of adsorbent material which results in two different coating thicknesses.

Figure 1: Fin-tube heat exchanger coated by PST method with SAPO34.

The key figures of the adsorption heat exchangers are given in Table 1. As a part of the aluminium fins is used to build up the adsorbent layer (consumptive crystallisation), the metal mass of the AdHEX decreases with the amount of adsorbent. This leads to an even higher mass ratio: with an increase of around 70% in adsorbent mass, the mass ratio rises by more than 90% (see Table 1).

Table 1; Key figures of AdHEXs

	WT-K17	WT-K18
Dimensions (finned part)	256 mm x 173mm x 50 mm	
Volume (finned part)	2.2 dm^3	
HEX area	2.59 m^2	
Number of tubes	16	
Inner diameter of tubes	9 mm	
Weight (metal)	1.075 kg	0.975
Weight (adsorbent)	0.14 kg	0.24 kg
Mass ratio (adsorbent/metal)	0.13	0.25

Characterisation in the single bed adsorption chiller at CNR-ITAE

A lab scale single bed adsorption chiller is used to characterise the dynamic behaviour of the two AdHEX under realistic operation conditions. The test facility is shown in Figure 2. External heating and cooling is provided by 3 hydraulic loops with 3 temperature levels that can be adjusted separately. Storage tanks provide a stable temperature at the inlet of each of the three HEX within the system (evaporator, condenser, adsorber). Information on the set-up and the method to determine the specific cooling power (SCP) and the COP can be found elsewhere [2]. Two temperature sensors are placed directly onto the fins to determine the temperature of the adsorbent. Thermal grease is used to guarantee thermal contact.

An overview of the different test conditions is given in Table 2. For the characterisation 3 main aspects have been examined:

- Duration of cycle τ_{cycle}
- Ratio of adsorption and desorption times within a fixed cycle time $R = \frac{\tau_{Ads}}{\tau_{Des}}$
- Variation of adsorption and desorption temperature.

Table 2; Test conditions

Parameter	Range	
Desorption temperature	85°C, 90°C	
Adsorption temperature	30°C, 35°C, 40°C	
Evaporator temperature	10°C, 15°C	
Condenser temperature	30°, 35°C, 40°C	
Cycle time	1.5 min– 6 min (plus duration of isosteric phases)	
Ratio adsorption/desorption time	1-3	
Weight (adsorbent)	0.14 kg	0.24 kg
Mass ratio (adsorbent/metal)	0.13	0.25

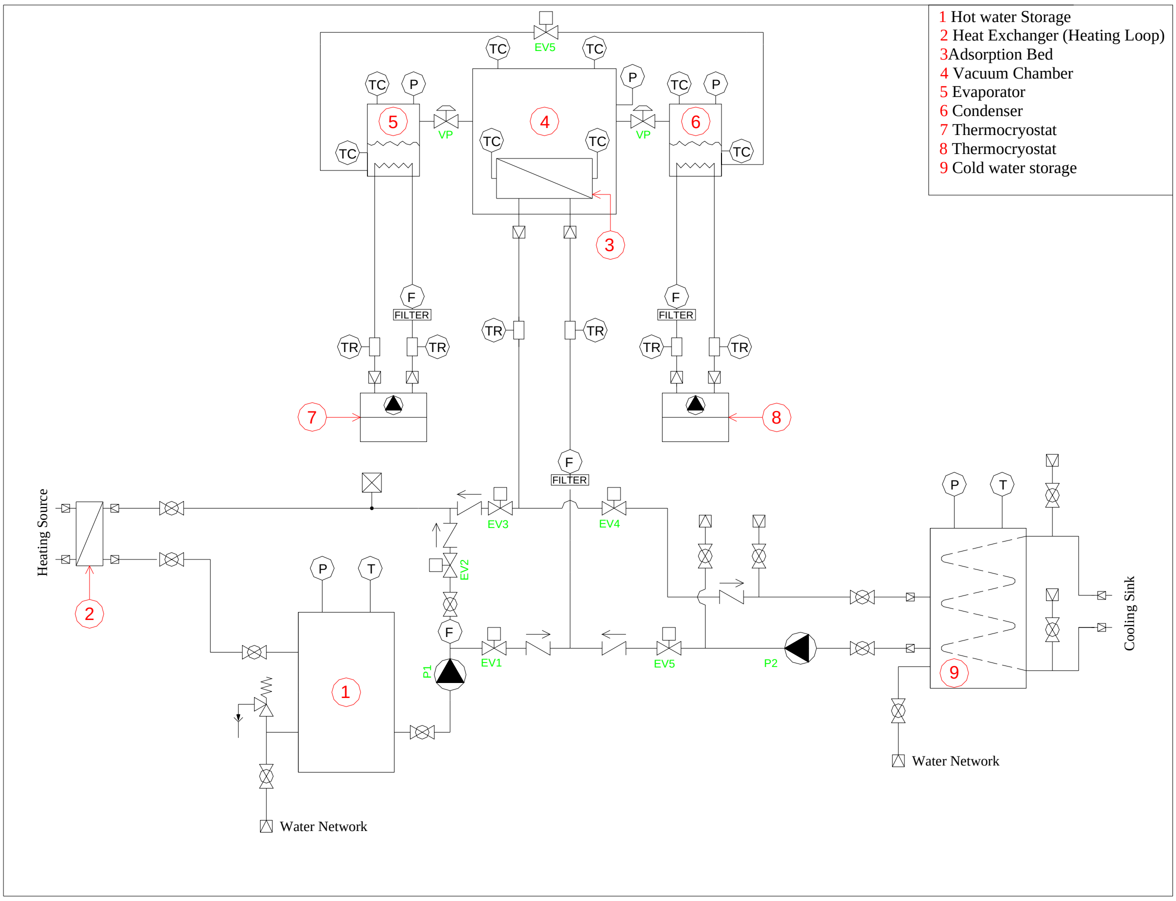

Figure 2: Schematic of the single bed adsorption chiller, 1: hot water storage, 2: heat exchanger (heating loop), 3: adsorption bed, 4: Vacuum Chamber, 5: evaporator, 6: condenser, 7.8: thermocryostat. 9: cold water storage.

Results and Discussion

The variation of cycle time shows a very fast kinetic of the AdHEX. The maximum specific cooling power is reached at 3 min for the AdHEX with 240g of adsorbent (WT-K18). A reduction of adsorbent mass by 100 g leads to even shorter optimum cycle times (2 min, WT-K17). High SCP are reached up to 73 W/dm³ (1195 W/kg adsorbent) with WT-K17 and 57 W/dm³ (540 W/ kg adsorbent) with WT-K18, respectively (see Figure 3). Other than expected, the higher amount of adsorbent in WT-K18 does not result in a higher cooling power. There seems to be a limitation of mass transfer due to the higher sorbent layer thickness.

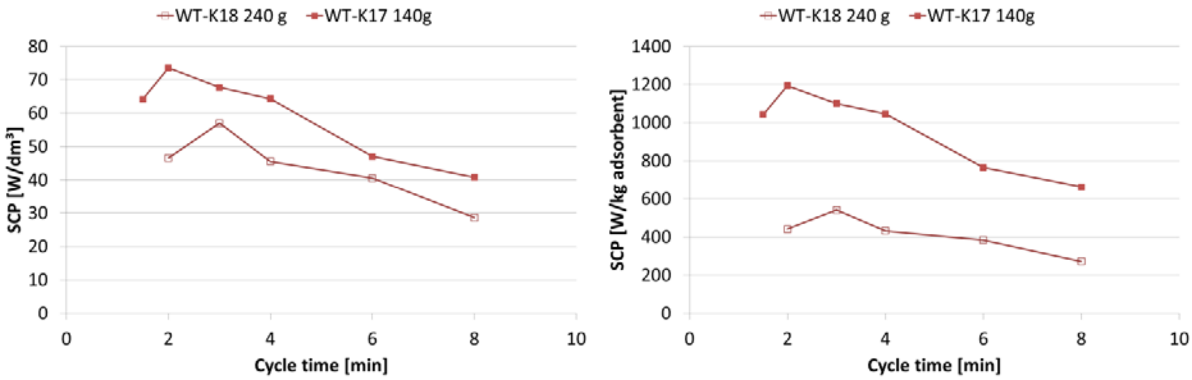

Figure 3: Specific cooling power (left: per volume HEX, right: per mass adsorbent) as a function of cycle time. R=1 at T_{des}=90°C, T_{ads}=T_{cond}=35°C, T_{Ev}=10°C.

This is also confirmed by the results shown in Figure 4. A longer time for desorption phase leads to a better performance.

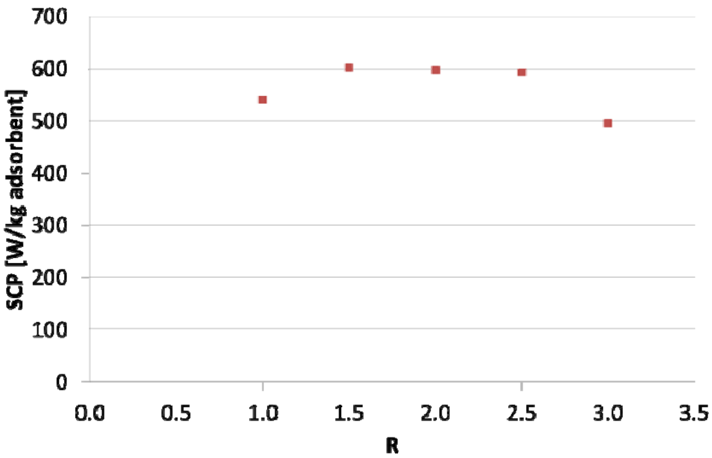

Figure 4: Specific cooling power of WT-K18 as a function of R for t_{cycle} = 2min at T_{des}=90°C, T_{ads}=T_{cond}=35°C, T_{Ev}=10°C.

The COP values reached are in the range between 0.15 and 0.27 (see Figure 5).

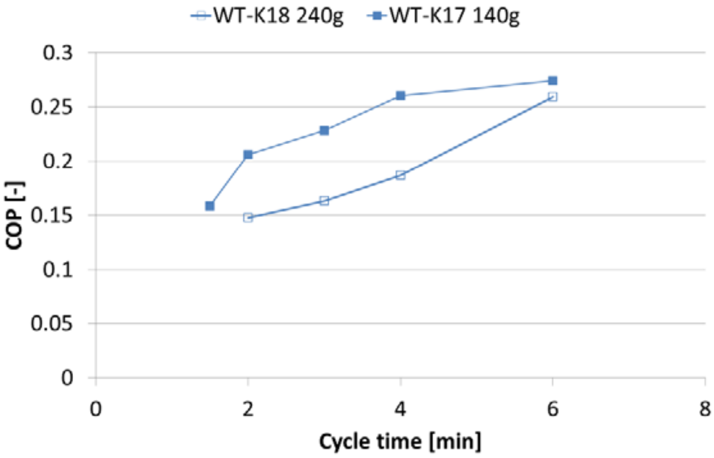

Figure 5: Coefficient of performance of cycle time. R=1 at T_{des}=90°C, T_{ads}=T_{cond}=35°C, T_{Ev}=10°C.

Finally, for a comparison to measurements that have been carried out in literature as well as with unpublished measurements at Fraunhofer ISE with the same sorption material, some experiments were out at other temperature levels (see Figure 6). The large decrease in SCP for a adsorption/condenser temperature of 40°C is due to the sorption behavior of SAPO34: between 30 and 40°C the sharp step in uptake can be observed within the equilibrium data.

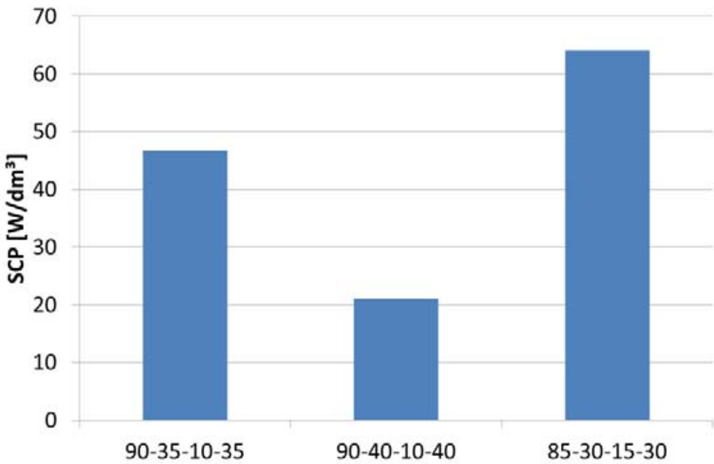

Figure 6: Specific cooling power of WT-K18 as a function of R for t_{cycle} = 2min at T_{des}=90°C, T_{ads}=T_{cond}=35°C, T_{Ev}=10°C.

Bauer [3] published a SCP of 350 W/dm³ HEX volume and a COP of 0.6 at 90% loading time (3 min, i.e. cycle time of min. 6 min) for a similar AdHEX at 15°C as evaporation, 30°C as adsorption and condensation, and 85°C as desorption temperature. As Bauer did not measure several cycles in a row but only one single adsorption step, these values can be seen as an upper limit. Within our measurements with a cycle time of 3 and 4 minutes, WT-K18 showed a SCP of 78 W/dm^3 and 64 W/dm^3, respectively. Similar measurements as done by Bauer will be carried out in a test facility at Fraunhofer ISE with the AdHEXs characterised at CNR-ITAE and will be presented in a joint publication.

Literature

[1] A. Freni, F. Russo, S. Vasta, M. Tokarev, Y.I. Aristov, and G. Restuccia, "An advanced solid sorption chiller using SWS-1L," *Applied Thermal Engineering*, vol. 27, Sep. 2007, pp. 2200-2204.

[2] A. Freni, A. Sapienza, I.S. Glaznev, Y.I. Aristov, and G. Restuccia, "Experimental testing of a lab-scale adsorption chiller using a novel selective water sorbent 'silica modified by calcium nitrate'," *International Journal of Refrigeration*, Jun. 2010, pp. 1-7.

[3] J. Bauer, R. Herrmann, W. Mittelbach, and W. Schwieger, "Zeolite / aluminum composite adsorbents for application in adsorption refrigeration," *International Journal of Energy Research*, vol. 33, 2009, pp. 1233-1249.